THE EXPLOSIVES ENGINEER

FORE-RUNNER OF PROGRESS IN MINING-QUARRYING & CONSTRUCTION

JANUARY-FEBRUARY • 1960

VOLUME 38 • NUMBER 1

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THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction

It seems that in almost any section of the West one can find a dam, a tunnel, or a hydroelectric plant either in the course of construction or recently completed to help meet the ever-increasing needs for water or power. One of these hydroelectric projects now under construction will augment the present utilities that serve the Sacramento, California, area—an area whose population has increased 80% in the past ten years. Peak power demand has skyrocketed 223%, and the annual power used has increased 175% during this period.

Part of the Upper American River Project is the Jaybird Tunnel, a 14-ft.-diameter horseshoe-shaped bore, 21,300 ft. long, which will convey water from Junction Reservoir to a penstock leading to Jaybird Powerhouse.

An interesting account of the overall project, with emphasis on driving the Jaybird Tunnel, is presented by Harold E. Russell, beginning on page 7.

• • •

Vibrations from blasting operations, which long have been the concern of quarrymen, are now becoming the bane of contractors, particularly those engaged in roadbuilding. Dr. L. Don Leet, professor of geology and seismologist in charge of the Seismograph Station at Harvard University, and the author of many books and technical papers on the effects of vibrations from blasting, has just completed an article on the vibration problems that are unique to construction blasting.

The first installment of Dr. Leet's paper starts on page 13. The second and final installment will appear in our March-April issue.

• • •

Two men long prominent in the heavy-construction field have been chosen to receive the 1960 Moles Awards—William Denny, executive vice president in charge of the Construction Department of Merritt-Chapman & Scott Corporation, and George M. Drake, president and general manager of Johnson, Drake & Piper, Inc. Official award ceremonies took place at the annual dinner held on January 27 at the Waldorf-Astoria Hotel, New York City.

More details of this announcement may be found on page 20.

• • •

Farrell Castellani, in his article "Underground Mining for Cement Rock," which starts on page 21, gives an interesting account of the early activities and present procedures of the Missouri Portland Cement Company in the Kansas City, Missouri, area. He traces the company's progress through more than 50 years of operation, describes the recently completed modern plant, and details the underground drilling, blasting, and removal methods that have made this plant a model of efficiency for producing cement rock.

• • •

Colorado School of Mines officials believe that a good technical education combined with practical experience better qualifies a graduate to take his place in the mining industry. So they make sure their students get that necessary practical experience by having their own mine. The school has a 99-year lease on an old mining property, the Edgar Mine, located at Idaho Springs. Undergraduates use this mine for such work as would be difficult to teach in a classroom. At the Edgar Mine, the students gain practical experience in mine surveying, mineral land surveying, stoping, drifting, and the proper use of explosives.

A description of the work carried on at the Edgar Mine, written by Robert Dyment, starts on page 25.

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Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

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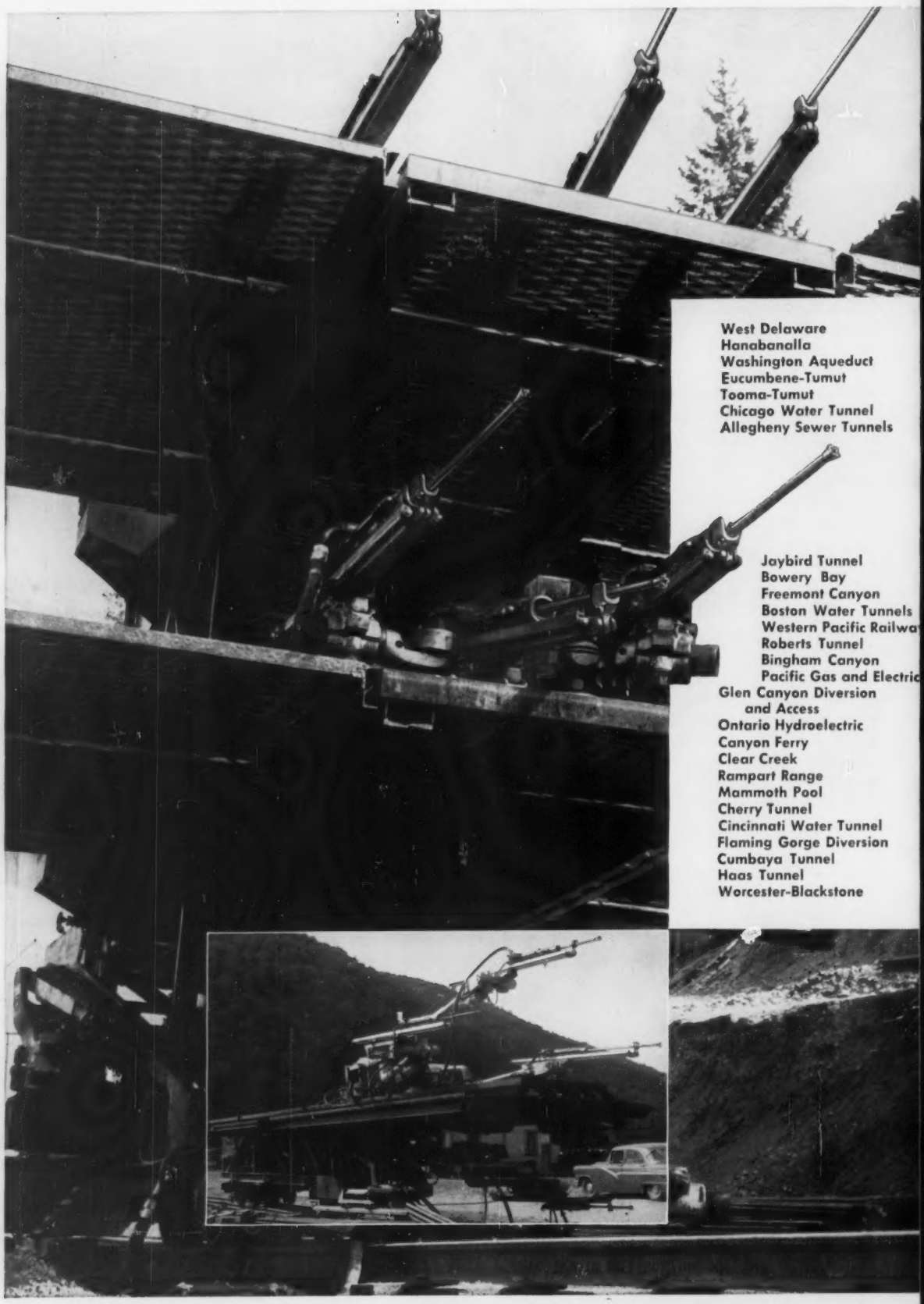

West Delaware
Hanabanalla
Washington Aqueduct
Eucumbene-Tumut
Tooma-Tumut
Chicago Water Tunnel
Allegheny Sewer Tunnels

Jaybird Tunnel
Bowery Bay
Freemont Canyon
Boston Water Tunnels
Western Pacific Railwa
Roberts Tunnel
Bingham Canyon
Pacific Gas and Electric
Glen Canyon Diversion
and Access
Ontario Hydroelectric
Canyon Ferry
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MANSELL LEHIGH MacLEAN

Mansell Lehigh MacLean

PRESIDENT

MacLEAN - GROVE & COMPANY, INCORPORATED

A Biography

IF Mansell Lehigh MacLean had begun his lifework building tunnels and highways at his birthplace, he would have run into water very quickly, for North Sydney on Cape Breton Island in the Maritime Provinces of Canada is close to water in every direction. Mansell Lehigh MacLean, president of MacLean - Grove & Company, Inc., and president of The Moles, was born in that center of fishing, shipping, and boatbuilding on December 6, 1904.

"Manse" comes of sturdy Scotch and Scotch-Irish forebears who can trace their lineage to the early settlers of Nova Scotia. His father's ancestors were among the first group of settlers to colonize Cape Breton Island when, in 1772, they migrated there with a large group of Scottish immigrants. His mother's people arrived a little later in Ontario, having first settled in the Lehigh Valley in Pennsylvania. It was Blanche Lehigh's family for whom the famous Pennsylvania anthracite region was named. But being staunchly loyal to the British Crown, the Lehighs took a dim view of the Declaration of Independence, and, following its signing, they journeyed to Ontario with other members of the United Empire Loyalists.

Manse attended school in North Sydney and was graduated from North Sydney High School in 1920. In 1924, he graduated from Acadia University, Wolfville, in the heart of Longfellow's Evangeline country. Later, he attended the Brooklyn Law School and is now a member of the New York Bar. During his college vacations, he got his first taste of the construction game when he spent two summers working on various highway and dam-construction projects. Upon graduation from Acadia University, he worked with a construction crew of Gibbs & Hill, Inc., building a power plant for the Virginian Railway and electrifying the system between Roanoke, Virginia, and Mullens, West Virginia.

In 1926 he joined Samuel R. (Subway Sam) Rosoff, at that time the dean of tunnel contractors. The next twenty-four years were spent with "Subway Sam" in building subways in New York City and tunnels in New York State and Mexico. Starting as a field engineer, he advanced through the position of cost engineer until, at the time of Mr. Rosoff's death, he was general manager and chief engineer of the Rosoff enterprises. After the dissolution of the Rosoff firm in 1951, Mansell L. MacLean joined with Philip Grove to form MacLean - Grove & Company, Inc., to specialize in tunnel and other heavy-construction projects. The first project of the new company was a highway near Watertown, New York, a joint venture with Washbourne Construction Company.

A job that had a great bearing on the future of the new firm was the building of deep liquid petroleum-storage facilities in Illinois for National Petro-Chemicals Corporation, a subsidiary of National Distillers. It was this experience under difficult conditions that gained for MacLean - Grove the invitation to participate in a joint venture with a German construction company in the driving of the first tunnel under the Rhine River at Dusseldorf, Germany. Other recent contracts were the third tube of the Hudson River Tunnel, with Mason & Hanger and The Arthur A. Johnson Corporation; a section of the New England Thruway, with The Arthur A. Johnson Corporation; and a five-mile section of the West Delaware Water Tunnel for the New York City Board of Water Supply, with Geo. M. Brewster & Son, Inc. MacLean - Grove is currently engaged in constructing a one-and-a-half-mile drainage tunnel for The Metropolitan District Commission of the Commonwealth of Massachusetts.

During his university days at Acadia, Manse met a coed—Masie Johnston of New Glasgow, Nova Scotia—who four years after graduation became Mrs. MacLean. The MacLeans live at 35 Byron Lane in Larchmont, New York. Mr. MacLean is president of The Moles and is active in the Canadian Club of New York, National Society of Professional Engineers, the New York State Society of Professional Engineers, and the Engineers Club of New York. He is president of the General Contractors Association of New York City. In 1959 Mr. MacLean was given an honorary doctorate by his alma mater, Acadia University.

Editorial

Technical and Nontechnical Approaches

Tunnel and highway contractors might well familiarize themselves with the vibration data set forth in a new article by Dr. L. Don Leet to be published in two parts, the first of which appears in this issue. Vibration problems are an old story to quarry operators, who have been plagued with vibration complaints, and even damage suits, from residents in nearby houses. Tunnel and highway contractors, on the other hand, generally have not run into this problem as often because many of their operations are conducted in remote spots far from any inhabited structures. As housing developments spread farther and farther, however, it is likely that more tunnels and highways will be built closer to dwellings, and vibration problems are likely to occur with greater frequency.

Dr. Leet has written a very competent discussion of the pressures built up and transmitted through rock and overburden following rock blasts. The article establishes that the careful use of delay caps can minimize the shock waves to the point where no damage will result, even to nearby houses.

A complicated formula, such as $ER = \frac{a^2}{f^2}$, while meaningful to an engineer, probably is not going to make much of an impression upon a housewife who has just come through the morning struggle of getting her husband off to work, the kids off to school, and has collapsed in a chair while she contemplates the tasks facing her through the remainder of the day. Something else is needed to persuade her that she need not worry about blasting.

A more practical approach would seem to be a pleasant-speaking ambassador who would call upon the residents, inform them that blasting is about to begin, and assure them there will be no damage to their homes from the vibrations they feel. Perhaps the best way of persuading the neighborhood that no damage will come to the homes would be to arrange a showing of the movie "Blasting Vibrations—Cause and Effect." Showings before service clubs and similar civic groups can be arranged by writing to THE EXPLOSIVES ENGINEER. It would be most important to do this early—before blasting begins and before people have made claims, even informally, that damage has resulted.

The movie, in which both Dr. and Mrs. Leet appear, will be helpful as a means of interpreting these data to housewives and other laymen.

The Cancerous Strike

Probably no one in the country is now uninformed on the steel strike and the serious consequences to our nation, which was paralyzed for lack of steel in many segments, indeed almost every segment, of the economy. For example, the widely advertised automobile industry's new models had to be delayed and that industry, at length, closed its plants one by one after the huge stocks of steel it had stockpiled were finally exhausted. And so it spread from one industry to another—closed down or slowed for lack of steel.

One phase of this spreading paralysis, and one which was particularly painful to explosives-consuming industries, was the slowdowns caused by the steel mills' failing to buy materials from their own suppliers. In this quarter, the mining industry and other explosives-consuming enterprises were also among the victims of the national paralysis.

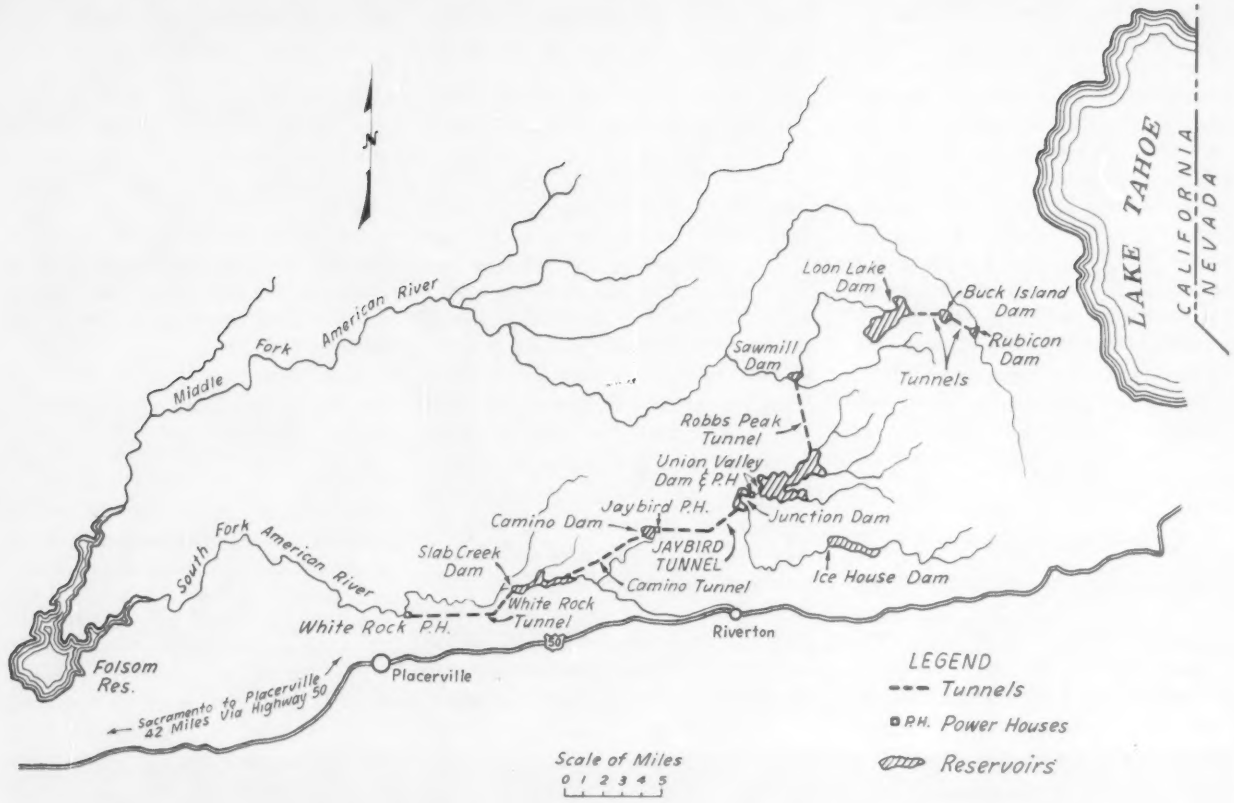
Obviously, the bituminous-coal industry was slowed considerably and some mines, notably the steel company-owned mines, were shut down completely. Other less publicized mines also suffered, or at least had to adjust operations drastically in an attempt to meet the ups and downs of steel industry requirements.

The preliminary report of the Bureau of Mines on 1959 mineral production reveals many of these minor tragedies, minor in so far as their effects on the economy are concerned, but quite major when the hardships which came to employes and their families are considered.

Scrap consumption, that bellwether of many economic trends, illustrates the frenzied operations of some of the industry's suppliers. In the first six months of the year, scrap consumption was up 62%, but in the second six months, consumption slumped so far that the year's figures are likely to be up only 14%, indicating near-zero operations for at least some part of the second half of the year.

Output of magnesite and dolomite required for basic refractories dropped 38% below 1958, primarily because of the strike. Many titanium metal-processing plants were forced to close in the latter part of the year; a shortage of basic slag for use in portland cement hampered cement production. And so it went.

Mining and quarrying also suffer from a steel strike, not for lack of steel, but because of the idleness of one of the best customers of the mines and quarries, the steel mills of the nation.



DRIVING THE JAYBIRD

The Jaybird Tunnel, a unit of the Upper American River Project, will help provide hydroelectric power to the Sacramento, California, area

HAROLD E. RUSSELL*

JAYBIRD TUNNEL, a 14-ft.-diameter horseshoe-shaped bore, 21,300 ft. long, is a unit of the Upper American River Project located about 75 miles east of Sacramento, California. The $85-million hydroelectric power development is being constructed by the Sacramento Municipal Utility District.

Frazier-Davis Construction Company of St. Louis, Missouri, was awarded the $5.2-million contract for the tunnel in June of 1958. This was 0.3% below the next higher bid, and the lowest of eleven proposals which ranged to a high bid of $8.9 million. The low bid of $150 per linear foot of tunnel was equivalent to a unit price for tunnel excavation of $23 per cu. yd. The time limits specified for completion of various sections of the work required that the equipment used be mobile and fully interchangeable, considerations which the contractor met with the use of truck-mounted drill carriages, and diesel-electric powered shuttle cars for hauling muck, the first time that this equipment has been used to excavate a tunnel of this length.

The project will utilize runoff from an area approximately 250 sq. mi. on the western slopes of the Sierra Nevada to develop a total of 3,870 ft. of power head, a peak generating capacity exceeding 200,000 kw., and a total annual output at the power plants of over 900 million kw.-hrs. Jaybird Tunnel, along with Ice House, Junction, and Camino Dams, and Jaybird Powerhouse form the first phase of the work that will have power on the lines by November, 1960. The completed project will include ten dams, four powerhouses, and seven tunnels with a combined length of 82,400 ft.

Area Growth

The spectacular postwar growth of the Sacramento area indicated that the district's peak power needs could be met only to 1961 by an existing power allotment from the California Central Valley Project. The population of Sacramento County increased 80% from 1947 through 1956. Peak power demand skyrocketed 223%, and annual power use increased 175%. Additional power resources were imperative to permit the continued growth of the area. Thirty-five years of planning were climaxed in 1955 by the authorization of a revenue bond issue to provide the facilities necessary to meet prospective power demands.

*Estimates Unit
Department of Water Resources
State of California

The completed project will accord with the principles of the California Water Plan developed by the Department of Water Resources and incorporated into the State Water Code by the California legislature. The plan is a framework for the development of water resources by all agencies in California in a coordinated manner to assure that available resources are developed fully for all beneficial purposes. Power production is the primary objective of the Upper American River Project. But water conservation, stream-flow regulation, and the development of recreational facilities at reservoir sites are also important project benefits.

Project Specifications

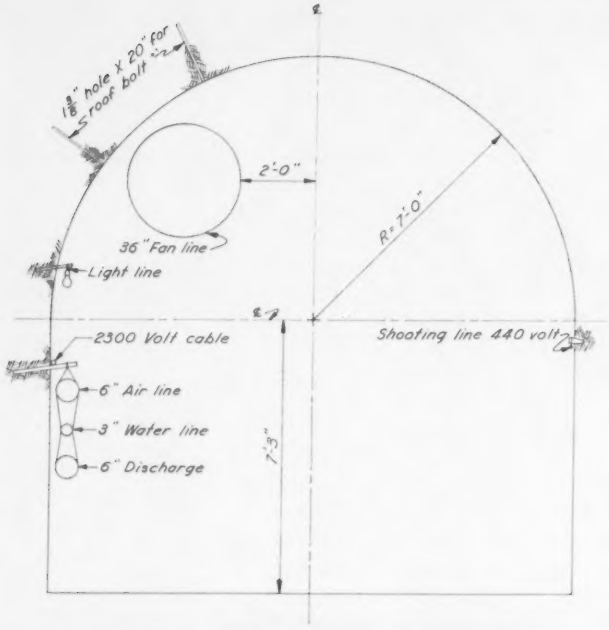
Jaybird Tunnel will convey water from Junction Reservoir to a penstock leading to Jaybird Powerhouse. The tunnel will be constructed to a grade of 0.0025 except for an inclined section about 300 ft. downstream from the intake portal. At this point the invert will drop approximately 60 ft. at an angle of 50°, then continue at grade. The total drop from intake to outlet will be 107.5 ft.

The work includes an adit 850 ft. long. The tunnel extends 2.5 miles to the intake from the adit, and 1.5 miles to the outlet portal. A rock-trap enlargement about 220 ft. long, 21 ft. wide, excavated 8 ft. below tunnel grade, and a concrete-lined surge shaft of 14-ft. finished diameter, 177 ft. deep from the excavated ground surface, are located near the outlet portals. Waste areas are designated at the portals. The bore will be unlined except at the adit intersection, at sections adjacent to the upstream and downstream portals, and where lining is required by ground conditions. Steel liner, 11 ft. in diameter, will be installed in the tunnel from the surge shaft to the outlet portal and stubbed out for connection to a penstock.

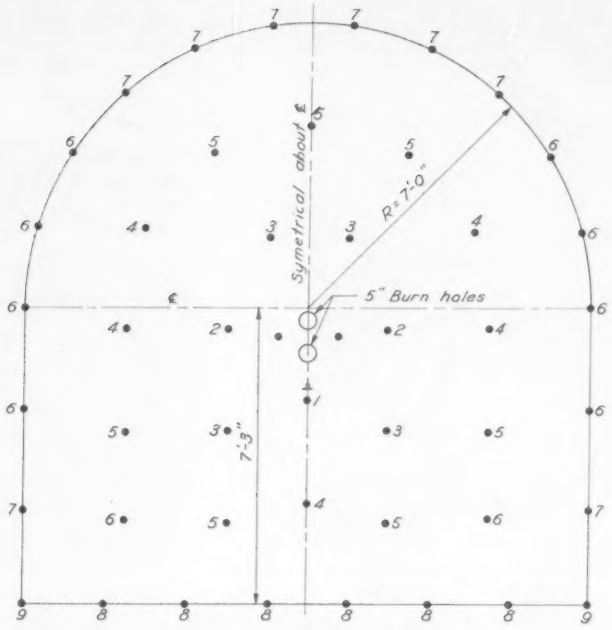
The bore is being driven through the Calaveras formation consisting of folded schists, phyllites, slates, quartzites, and hornfels. Andesitic agglomerate mudflow-type material, comprising fragments from pebble to boulder size, in a well-hardened, fine-to-medium-grained tuffaceous matrix, overlies the metamorphic rocks along a portion of the alignment. The volcanic material was encountered near the outlet portal.

Specification provisions prescribe the contractor's plan for executing the work. Completion date for the rock-trap section and all work downstream therefrom was set for December 1, 1959, and this segment could not be used for access, or as a ventilation duct, after this date. No tunnel excavation was permitted from a heading at the intake portal before August, 1959, and all work in this vicinity is to be completed by May 1, 1960. All contract work is to be completed by August 1,

UPSTREAM HEADING: An air-operated Joy mucking machine has no trouble removing the well-broken rock at the upstream heading.



TUNNEL UTILITIES: This diagram shows the location and size of the various utilities required for the rapid completion of the Jaybird Tunnel. The shooting line is located on the side opposite the light and power lines.



DRILL PATTERN: The tunnel face contained 47 parallel 1¾-in.-diameter holes, each 11 ft. deep, plus two 5-in.-diameter burn holes. Numbers by holes indicate order of firing. This round produced excellent fragmentation.

1960. Liquidated damages of $200 per calendar day were specified for failure to complete the work as stated.

The contractor's construction plan followed a logical sequence to meet these scheduled dates. Approach roads were completed as required. A temporary plant was set up at the outlet portal and work was pushed to completion in that vicinity. At the same time, a permanent plant was set up at the adit portal, the adit was completed, then work was started on the tunnel sections upstream and downstream from the adit. The alternate heading method was first used to drive the tunnel, with a drilling crew and a mucking crew working each face until the equipment at the outlet was free. The single-heading method was then adopted at each section when the bore had been advanced beyond the point of economical working range for the alternate heading method. The start of work at the inlet portal is contingent upon the progress of driving the downstream tunnel section from the adit.

Drilling Procedure

Tunnel faces are drilled to a pattern of 47 parallel 1¾-in.-diameter holes spaced for reliever, trim, and lifter shots, and two 5-in.-diameter burn holes, 8 in. on centers vertically, located on the center line and immediately below the tunnel spring line. Holes are drilled 11 ft. deep.

Drill carriages consist of heavy steel frames mounted on 27-D Euclid truck bodies. Three Gardner-Denver Model No. 93 drifter drills, 3½-in. bore, with 1¼-in. round chucks, mounted on aluminum guide shells, with 10-ft. screw feeds, are located under a forward platform, and two similar machines are mounted above the platform. Gardner-Denver JTB tripod-style hydraulic booms, equipped with Model DPU hydraulic positioning devices, provide powered maneuverability to reach any area of the face. The burn holes are drilled with a Gardner-Denver Model DH-143 drifter, 5½-in. bore, mounted on an aluminum shell, with a 14-ft. screw feed. Hole spotters on the small machines, and a heavy-duty centralizer on the larger machine, limit drill-rod vibration. The hydraulic system of the booms is powered by feeder lines from two air-operated Gardner-Denver Model JMA hydraulic pump units connected to a 15-gal.-capacity oil tank hung from the platform. Return lines feed back to the storage tank. A 6-in. manifold supplies air to the drifters. Gardner-Denver Model LO7 line oilers in the air supply piping near the hose connections lubricate the drifters. Water for drilling is supplied by a 2-in. manifold. Bull hoses, 3-in. diameter for air, and 2-in. diameter for water, connect the drill-carriage piping systems to tunnel-supply lines.

No steel changes are made at the face. Bethlehem and Crucible 1¼-in. round, carbon steel, lugged-shank drill rods, with H-type threads, are used for the No. 93 drifters. The detachable bits, carbide-insert, 1¾-in. diameter are Ingersoll-Rand, Model No. 116. Gardner-Denver 1⅞-in. hexagonal drill rods, carburized, with Brunner & Lay 5-in.-diameter, carbide-insert, Rok-Bits are used to drill the burn holes. The bits are dressed in a shop located near the adit. Drill steel is independently processed off the site of the work at shops located in Sacramento or Sonora.

Air is supplied at the adit portal by a battery of portable compressors consisting of three Ingersoll-Rand Gyro-Flo 900 c.f.m., one I-R 600 c.f.m., and one Gardner-Denver 900 c.f.m. No receiver or aftercooler is used. Air is piped in a 10-in.-diameter line through the adit, then in 6-in.-diameter similar lines to the headings. Water is sup-

plied to the faces in 4-in.-diameter lines leading from a tank mounted on the hillside above the adit portal.

Electric power is transmitted into the tunnel at 2,300 volts through Parkway cable and is stepped down at 1,000-ft. intervals by dry-type transformers to 110 volts for lighting, and 440 volts for firing. Illumination is provided by lines with globes spaced at about 25-ft. intervals.

Ventilation is provided by Joy Axivane fans, 75 hp., 440 v., 3,450 r.p.m., blowing 36,000 to 37,000 c.f.m. to the faces through 36-in.-diameter, 12-gauge asphalt-dipped, spiral-welded steel pipe with rubber-gasketed joints. Each heading is ventilated by a pipe leading through the adit, then each tunnel section. The installation of ventilation pipe is facilitated by a fastener developed by the Bethlehem Steel Company. The fastener consists of an eye-bolt hanger, 2½ ft. long, fabricated from ¾-in.-diameter rod, and threaded at the anchor end to receive a K-type expansion shell used in rock bolts.

Blasting Technique

Drilled faces are loaded with Gelamite® 2, a semigelatin of 45% strength, 1¼ by 8-in. cartridges. The powder factor varies from 3 to 5 lb. per solid cubic yard of rock. No stemming is used. No Vent® caps, 0 to 9 delay, with 14-ft. plastic-covered leads, are used to detonate the primers. Leads are hooked to a parallel circuit of two loops of 12-gauge aluminum wires fastened to four dowel pegs driven into the face. The bus wires are connected by No. 20-gauge plastic-covered wires to the No. 8-gauge rubber-covered blasting circuit strung on the tunnel side opposite the light and power lines. The blasting switch is mounted about 1,500 ft. from the face. A jumper from the power line is plugged into the blasting switch for firing. The switch may be unlocked to fire a shot only by a shifter.

Tunnel excavation averages 6.5 cu. yd., solid, per linear foot. The 11-ft. round breaks about 120 cu. yd. of loose muck which fills 10 to 12 shuttle cars.

The burn cut adopted has proved to be very effective in the material encountered to date. The rock breaks very well, with a minimum of secondary shooting required. The muck is piled close to the face, and cannonading does not damage utility facilities. The absence of flyrock permits mucking operations to proceed almost uninterruptedly, with little time spent on shaping up the muck pile.

Mucking Operation

Muck is excavated with air-powered, Joy Model No. JSL-7 overshot muckers, crawler mounted, equipped with 11-cu. ft. buckets. The shovel cycle is quite short; with an experienced operator working, a good muck pile can average 8 seconds per cycle.

The muckers dump into the hopper of a Joy Model No. TL-11-27 RE elevator loader equipped with a 30-in.

DRILL CARRIAGE: The drill carriage consists of a heavy steel frame mounted on a 27-D Euclid truck. Five Gardner-Denver drills are mounted on the carriage, three on the bottom platform and two on the upper platform.

STEEL SUPPORTS: The deck of the drill carriage makes a good platform from which to erect the steel supports. It was necessary for workmen to install steel supports in about 28% of the tunnel's length.

flight conveyor powered by two 10-hp. air motors. The equipment was altered at the site to facilitate loading the shuttle cars to capacity.

The Joy Model No. 60-E-12 diesel-electric shuttle cars have a level capacity of 10.5 cu. yd., which has been increased to 12 cu. yd. on the job by the addition of a 6-in. metal skirting. A built-in hopper at the front end of the car feeds muck to a 40-in. flight conveyor traveling on a deck which extends through the car body at wheel-axle height. Deck plates have a renewable wearing surface of ¼-in. abrasion-resistant steel. The conveyor speed can be regulated to a maximum of 60 ft. per min. The cars are powered by three-cylinder, two-cycle diesel engines, rated 82 hp. at 2,000 r.p.m., directly connected to a 50-kw. generator. Two 250-volt, d.c., 15-hp. motors provide power for traction, and another 15-hp. motor supplies power for the flight conveyor. Power for the conveyor motor is transferred automatically from traction by the same foot pedals used for traction control. The cars are equipped with a scrubber conforming to U.S. Bureau of Mines Schedule 24 for diesel engines operating in noncoal mines. Motor exhaust is piped through a solution of sodium sulfite and hydroquinone to remove ethyl aldehyde and formaldehyde gases prior to release to the atmosphere. The cars are rated at speeds of 7.5 m.p.h. empty, and 6 m.p.h. loaded, on level ground.

The mucker and loader are planned to operate continuously during the mucking operation. The hopper and conveyor of the loader have a capacity of about 6 cu. yd. Loading of a shuttle car is started immediately when it arrives at the face. Normally, a car can be loaded in five minutes. Traffic control is facilitated by turnouts, long enough to hold two shuttle cars if necessary, spaced at 1,000-ft. intervals in the tunnel, and by a system of block signals operated by pull switches. The spoil area is located in a canyon adjacent to the adit, which simplifies muck disposal. The shuttle cars are stopped close to the edge of the bank and muck is discharged down the slope by the flight conveyor. A car can be unloaded in less than 1.5 minutes.

The tunnel invert is maintained reasonably level by rock fill graded with a Caterpillar Model No. 12 motor patrol. Muck is crushed by an Iowa Manufac-

MUCKING: After a blast the muck is excavated by a Joy Model JSL-7 overshot mucker. The loading cycle with an experienced operator averages 8 seconds.

Upper American River Project — Sacramento Municipal Utility District

Project Statistics

TUNNELS

Name	Diameter (feet)	Length (feet)
Rockbound	12	1,040
Buck—Loon	12	8,450
Robbs Peak	12	22,000
Union Valley	19	1,970
Jaybird	14	21,300
Camino	14	25,700
White Rock	21	24,000

DAMS

Name	Maximum Height (feet)	Crest Length (feet)	Capacity (acre-feet)
Rubicon Diversion, rock fill	28	2,860	2,160
Buck Island, rock fill	42	710	1,371
Loon Lake, rock fill	90	2,030	70,000
Sawmill, con. arch	98	424	500
Ice House, rock fill	148	1,600	46,000
Union Valley, earth fill	428	1,860	271,000
Junction, con. arch	168	520	3,250
Camino Diversion, con. arch	175	700	2,400
Slab Creek, con. arch	206	1,200	17,000
White Rock, Afterbay, con. gvty.	70	380	3,700

PENSTOCKS

Name	Diameter (feet)	Length (feet)
Union Valley	10	150
Jaybird	11 - 9.25	2,500
Camino	11 - 9	1,600
White Rock	15.5 - 14.5	1,020

POWER PLANTS

Name	Static Head (feet)	Installed Capacity (kw.)
Union Valley	420	33,000
Jaybird	1,540	133,000
Camino	1,050	86,000
White Rock	860	150,000

turing Co. Cedar Rapids portable jaw-crusher located at the adit portal, loaded into shuttle cars with an International TD-9 tractor equipped with a Drott skid shovel, and distributed within the tunnel as required.

In sound rock requiring no steel support, progress has averaged from 42 to 48 ft. per day per heading, requiring four to five shots each three shifts. A typical cycle would consist of the following times:

	Hr.	*Min.*
Drill	2	0
Load	0	45
Blow	0	15
Muck	2	30

The crew at each heading consists of a shifter, six miners, a nipper, a mucking machine operator, three shuttle car operators, and an electrician. A heavy-duty mechanic and a compressor operator serve both headings. During the day shift, a four-man bull-gang installs piping and maintains the tunnel invert. Six mechanics, a drill doctor, a bit grinder, an electrician foreman, and a powderman support the heading crews.

Key Personnel

Howard Odell is project manager for Frazier-Davis at the work. He is assisted by Ted McCoy, general superintendent; Bob McCoy, project engineer; Tom Warefield, safety engineer; John Etheridge, master mechanic; Kenneth Cooper, electrician foreman; Lon Lentz, office manager; and Ralph Christian, Herman Fossum, Anthony Martin, and Al Lamb, walkers.

George Frazier is president of Frazier-Davis Construction Company; Grant Wyatt, Jr., is executive vice president; and Roy Gunther, vice president, is in charge of tunnel construction.

Bechtel Corporation of San Francisco was engaged by the district for design, field engineering, and inspection. D. S. Culver is project engineer, William Stinchfield, resident engineer, and R. L. Deming, assistant resident engineer. Richard Perley is the inspector at the site.

Clyde Spencer is project engineer for the Sacramento Municipal Utility District. He is assisted by J. J. Mattimoe, Joseph Carniglia, and Du Wayne Lidke.

HIGHWAY BLASTING: With many of the expressways passing through populated areas, the highway contractor must carefully supervise his blasting technique. This well-planned and well-executed blast was fired during the construction of the Connecticut Expressway.

VIBRATIONS From Construction Blasting

Part I of this two-part article discusses vibrations that are unique to construction blasting; the second installment will outline ways to minimize such vibrations

L. DON LEET*

PART I

VIBRATIONS from blasting, and the effects of such vibrations on structures, have been discussed in a number of publications. Although many of these were focused on quarry operations, construction blasting, of course, has much in common. There are, however, problems unique to construction blasting that have not received special attention.

Quarries usually work to a relatively high vertical face and strive for a pile of broken stone at the foot of that face in pieces of a size readily handled by shovels, trucks, and a crusher. They may be working a strong, brittle granite, extensively jointed basalt, variegated limestone, or soft, friable sandstone. Each of these involves a special combination of procedures and results, which, once worked out, often apply for the life of a quarry. Contractors, on the other hand, may encounter several or all these rock types along a single stretch of highway construction. In a blasting sense, many trenches in rock are small-scale quarries, while large road cuts in rock also have many of the problems of a quarry, although limited in volume

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and duration of blasting. Tunnels present a unique combination of problems. In comparison with quarries, tunnels require very small quantities of explosive and long-period delays of the order of a second or more between detonations, with a free face that is itself buried below the ground surface. The by-product vibrations that affect the neighborhood are correspondingly quite different.

Also, there are some recent advances of knowledge in the whole field that have not been described to general users of explosives. So this seems like an appropriate time to add some footnotes to the existing literature. The present discussion is abstracted from parts of a monograph called *Vibrations from Blasting Rock*, being printed by Harvard University Press.

Blast Holes

The process of blasting rock to facilitate its removal involves a series of steps in preparing the blast, and a complicated sequence of events during and following detonation of the explosive. Each of these has its influence on vibrations, which are waste by-products of the operation, and on the characteristics of these vibrations that make them perceptible to people and govern their effects on buildings, pipelines, or other works of man.

Preparations for a blast begin with drilling holes into the rock for receiving the explosives. The size and depth of these holes as well as their separation from each other, called the spacing, and from any free face to which the rock is to be broken, called burden, have a bearing on the results. The location of the explosives in the holes, and the quantity of explosives required to break a specified volume of rock then need to be considered.

DRILLING AND LOADING. The size, depth, and spacing of the drill holes, as well as the quantity and location of the explosives in the hole, have a definite bearing on vibrations resulting from blasting.

The most general rule for the effect of these operations on vibrations is that *arrangements of holes and explosives which produce the most efficient breakage of rock automatically produce a minimum of vibration.*

The Explosive

Choice of the explosive involves consideration of the properties of explosives and of the rock. Explosives differ in density, in strength, in the rate at which they detonate, in their resistance to water, and in the energy they apply to breaking rock. Their capacity for generating vibrations results from combinations of these factors.

An explosive is a compound or mixture of compounds that reacts to heat or shock by decomposing rapidly into other compounds, mostly gases. The most widely used commercial blasting explosives are combinations of carbon, hydrogen, nitrogen, and oxygen so balanced that there is sufficient oxygen to oxidize the carbon and hydrogen to carbon dioxide and steam.

An energy- and gas-producing component, such as ammonium nitrate, NH_4NO_3, with carbon, may be mixed with a sensitizing compound such as nitroglycerin, $C_3H_5(NO_3)_3$. Pure nitroglycerin is so sensitive that it is dangerous to handle, while pure ammonium nitrate is the opposite extreme, difficult to detonate, even intentionally. But when these are combined in proper proportions, the result is an explosive that has some of the best features of both.

When cotton is treated with nitric acid, then the resulting *nitrocotton* is dissolved in nitroglycerin, a jelly is formed that may range in density from a thick, viscous liquid to a tough, rubbery substance insoluble in water. This is the base for *gelatin dynamites*. There are also *ammonium gelatins*, in which a portion of the nitroglycerin is replaced by ammonium nitrate.

Compounds that can be made to explode, but contain no nitroglycerin and are insensitive with ordinary handling, are sometimes referred to as *blasting agents* to distinguish them from the more sensitive compounds to which the term *high explosive* was originally applied. In this discussion, however, we are making no special effort to maintain this nicety of terminology, and designate as an explosive anything that explodes, no matter how easy or difficult it is to make it do so.

VERTICAL AND HORIZONTAL JOINTS: Vertical and horizontal joints can be seen on the rock face of this massive dolomite formation in Wisconsin. Blocks broken away from the face are outlined by joint surfaces.

The chemical changes that take place as an explosive converts from solid to gaseous compounds proceed at different rates in different explosives or in a given explosive under different conditions of confinement. They may be so slow that the gases escape as they form, and there is simple burning. When they are so fast that they are completed before the gases have time to expand appreciably, the process is called *explosion*, or *detonation*. Detonation occurs when the products of chemical change, started by shock or heat, set up a pressure boundary that, in turn, initiates chemical change in neighboring material. This pressure front moves through the explosive, compressing and heating it to the point of decomposition as it passes. The process, once started, is self-sustaining, and the rate at which detonation moves through it is an important characteristic of an explosive, since it governs the pressure build-up available for the job to be done.

The energy content of an explosive determines the work it can do. In absolute terms, it can be defined in British thermal units (B.t.u.) per pound. In relative terms, it is sometimes called the *weight strength*, and expressed as a percentage of the energy of an equal weight of nitroglycerin.

Nitroglycerin, or *straight*, dynamites are manufactured with varying fractions of nitroglycerin in their composition. A 60% straight dynamite, for example, actually contains 60% of nitroglycerin by weight. It is not three times as strong as 20% straight dynamite, however, because there are other energy-producing compounds present. And in going from a 20% dynamite to a 60%, although the energy obtained from nitroglycerin alone is trebled, the contribution of the other ingredients decreases from 80 to 40% to partially counterbalance the gain from nitroglycerin. So 60% straight dynamite instead of being three times as strong

Table I

PERFORMANCE GUIDES FOR CERTAIN EXPLOSIVES*

Explosive (see notes below table)	Specific Gravity	Energy B.t.u./lb.	Pressure lb./in.^{2}	Rate of Detonation ft./sec.	Characteristic Impedance lb.-sec./in.^{3}
(1) NG	1.6	650	2,939,000	26,250	47
(2) 50% NG	1.5	575	2,131,000	22,640	38
(3) 10% NG	0.98	450	632,000	13,125	14
(4) AN-C	1.0 0.8	436 430	679,000 429,000	13,900 12,000	15 10

*Modified after F. W. Brown, "Simplified Methods for Computing Performance Parameters of Explosives," Bulletin, Missouri School of Mines and Metallurgy, Tech. Ser. 94 (1957), pp. 123-136.

Notes on Explosives

(1) Nitroglycerin, $C_3H_5(NO_3)_3$.
(2) 50% nitroglycerin, 2.3% nitrocotton, 41.5% ammonium nitrate, 5.5% cellulose, 0.7% minor ingredients.
(3) 10% nitroglycerin, 80% ammonium nitrate, 10% cellulose.
(4) 93% ammonium nitrate, 7% carbon.

as 20% is actually about one and a half times as strong.

The effectiveness of an explosive in breaking rock and in generating vibrations depends on the total energy it releases, the rate at which this is released, and the efficiency with which the energy is transmitted to surrounding rock. These factors are not controlled by any single property of the explosive, of course; on the other hand, total energy content is a very useful characteristic by which to rate explosives relative to one another. Table I shows this figure for some explosives. This table also has a column showing a quantity called characteristic impedance. This is density times velocity of detonation, and its use is discussed later when we discuss the impedance of rocks.

When the density of an explosive is relatively high, its grains are closely packed in contact with one another and the shock front of detonation is communicated from grain to grain more efficiently than if the grains are loosely packed to give lower density. The effect of this is shown in Table I, where rate of detonation and pressure are directly related to density (expressed as specific gravity). High rate of detonation and high initial pressure are important in breaking many rocks by the processes described below.

Rupture of Rock by Blasting

When an explosive is placed in a hole drilled into rock and is detonated, the first result is development of high pressures from the gases that form. Those listed in Table I cover the range of explosives commonly used for blasting rock, and all exceed the greatest strength of all rocks. As a result, rock immediately around the explosive is crushed.

The pressures reduce very quickly, however, to values below the compressive strength of the rock. Where this happens, crushing stops and the remaining energy moves into unbroken rock as a wave of pressure, sometimes called the *shock front*, traveling at approximately the speed of sound in the same rock, but not breaking it.

Within a few feet of the crushed zone, if the shock front reaches a *free face*, that is, a surface where rock stops and air begins, the wave of pressure is reflected back into the rock as a wave of tension. Momentarily, then, a few inches back of the free face, rock is being pushed outward by trailing parts of the pressure wave and at the same time pulled outward by the reflected tension wave. If the combination of these two gives a total strain great enough, the rock breaks off and is projected away from the free face. The onrushing remainder of the pressure wave then finds a new free face to reflect it as a tension wave, and the process may repeat itself several times. The exact number of such repetitions, in fact, can be predicted from data on the length of the pressure wave combined with the tensile strength of the rock.

If the charge is large enough, crushing of rock immediately around the explosive, and rupture by reflection of the shock front from a free face are followed by pressures of the expanding bubble of hot gases which push the remaining rock, or burden, toward the free face as they churn and break it in escaping to the air.

A great deal about the mechanism of breaking rock by a reflected shock front has been learned from studying craters produced by charges buried in rock.[1]

To conduct a crater test, a charge of explosive is placed in a hole drilled into rock, and granular material called stemming is used to fill the rest of the hole. Usually the hole is vertical. The explosive is then detonated, broken rock removed, and the dimensions of the crater determined.

A striking feature of the results of some of these crater tests was the relationship between depth of charge and depth of the resulting crater. A charge at shallow depth produced a small crater that bottomed at the charge depth. Placing the same charge deeper produced a larger crater at first, then as depth increased still more, the

[1]Wilbur I. Duvall and Thomas C. Atchison, "Rock Breakage By Explosives," *U. S. Bureau of Mines Report of Investigations 5356*, Sept., 1957. This publication contains an extensive bibliography.

COLUMNAR JOINTING: Sometimes a special pattern of columnar jointing is found in basalt. Here is an example of extreme development of this type found in Devil's Postpile National Monument.

crater radius remained about the same but the crater depth was significantly less than the charge depth. Finally, charge depths were reached in all rocks where no crater was produced.

Evidence was produced by some of the crater tests showing that the breakage of rock to form the craters was achieved by force transmitted through rock which remained unbroken in the transmission process. In those tests, however, there was still a connection from the charge location to the ultimate crater by way of the drill hole used for placing the charge. It is possible, of course, that pressures and gases could have traveled up the hole and participated in crater formation. To investigate this, the Bureau of Mines conducted a special series of tests in a limestone in which the explosive charge was placed by the use of horizontal holes, and there was no connection by drill hole or other opening from the charge upward to the surface. The horizontal holes were long enough, and sand-stemmed, so that gases did not escape through them. Gases also failed to reach the surface. Under these conditions, when the charge was large enough, surface craters were still formed. All such craters were formed by the reflected shock fronts, and solid unbroken rock remained between the crater and the explosive, while escaping gases did not participate at all in crater formation.

When charge depth was so great that no crater formed, there was still cracking in the shape of a crater in some cases, outlining a *potential crater zone* or zone where a crater would have formed if there had been enough explosive.

This potential crater zone has an important bearing on effects at the surface in some types of blasting, and on hazards to existing buildings, to

PARALLEL JOINTS: When the mass of distorted metamorphic rock was blasted, it broke in such a way that a set of nearly parallel major joints was revealed, as indicated by the arrows. They are nearly edge-on and incline slightly from the vertical.

JOINT SURFACES: Joint surfaces blocked out pieces of massive granite surfaces of easy breakage when this rock was blasted for a road-construction job in Massachusetts.

pipelines, and to other works of man.

In most commercial blasting, the rupture of rock by reflected strain pulses is supplemented by work done by the expanding gases of an explosion. These supply the energy which moves the entire rock mass, or *burden*, that is broken from a face and deposited in fragments at its base. For a given quantity of explosive, massive movement of the burden begins after an interval which is proportional to the thickness of the burden and several times greater than the time required for the shock wave to reach the face and produce cracking by reflection. The velocity with which the burden moves out has been reported as inversely proportional to the square root of the rock weight.[2]

Effect of Rock Characteristics

The general principles of rock rupture by blasting have been discovered and investigated primarily in small volumes of nearly uniform rock masses. Rupture by reflected tension waves, for example, was studied in small-scale crater tests and in laboratory tests. And massive movements of burden produced by expanding gases were measured on small volumes in shallow bench blasting.

These two mechanisms accomplish the rupture of rock, but cannot be used to explain the details of breaking in most actual commercial operations, because such details are governed to a high degree by features of the rock itself. Chief among these are *joints*.

A joint is a natural, or "built-in," break in a rock mass where there has been no relative movement of the blocks on each side of the break. (If one side has moved relative to the other, the break is called a *fault*.) Joints occur in all kinds of rock and in every rock exposed at the surface. They are universal.

Joints always occur in sets, never singly. The spacing between them ranges from just a few inches to a few yards. Usually, the joints in any given set are almost parallel to one another, but the whole set may run in any direction—vertically, horizontally, or at some other angle. Most rock masses are traversed by more than one set of joints, often with two sets intersecting at approximately right angles.

A pattern of essentially horizontal joints is called *sheeting*. Here the joints occur fairly close together near the surface, but less and less frequently the deeper we follow them. After we have traced them a few tens of feet below the surface, they seem to disappear altogether. Even at depth, however, the rock shows a tendency to break along surfaces parallel to the surfaces of sheeting above. This type of jointing is especially common in masses of granite.

In *basalt*, the dark, dense, igneous rock popularly known as *"trap rock,"* a special pattern of jointing is sometimes found. It consists of breaks in the rock which outline columns that are six-sided in perfect development. It is known as *columnar jointing*. Even where columnar jointing is not prominently developed, basalt is generally characterized by extensive jointing and, for that reason, easily reduced to fragments of workable size by blasting.

When explosives are used to break rock, joints often control the pattern of rupture. If the dominant joints in a blasting face are steeply inclined, there is a hazard of slides of rock masses bounded by joints and loosened by blasting, if the face is nearly parallel to the joints.

There are two other characteristics of rocks that are important in determining their reaction to vibrations from blasting. These are *elasticity* and *characteristic impedance*.

Elasticity is measured by the speed, V, with which elastic waves traverse a rock:

$$V^2 = \frac{\text{Elasticity}}{\text{density}}$$

If we represent density by d, this leads to:

$$dV^2 = \text{Elasticity}$$

By definition:

$$dV = \text{Characteristic Impedance}$$

Ordinarily, the speed of compressional waves is the one most easily determined, so it is usually used in this

(Continued on page 30)

[2]Charles H. Noren, "Blasting Experiments in Granite Rock," Symposium on Rock Mechanics, *Colorado School of Mines Quarterly*, Vol. 51, No. 3 (1956), pp. 212-225.

WILLIAM DENNY

GEORGE M. DRAKE

THE MOLES AWARDS

William Denny and George M. Drake receive plaques and citations for outstanding contributions to construction progress

THE highest honors in the heavy-construction industry—The Moles Awards for 1960—were presented to two men who started as construction "stiffs" and worked their way through the ranks to head the world-wide operations of two of the nation's biggest construction firms.

Cited for "outstanding achievement in heavy construction," William Denny, executive vice president in charge of the Construction Department of Merritt-Chapman & Scott Corporation of New York, and George M. Drake, president and general manager of Johnson, Drake & Piper, Inc., of Minneapolis, are the twentieth pair to receive the bronze plaques and citations given annually by The Moles to one member and one nonmember. Formal presentation of the honors was made at the annual Moles Awards Dinner, held on January 27 at New York City's Waldorf-Astoria Hotel. Announcement of the selections was made by Mansell L. MacLean, president. The awards are considered the highest recognition that can be given to individuals for service to the construction industry.

The Moles, one of America's oldest construction organizations, is composed of the leaders of the nation's heavy-construction industry—builders of tunnels, dams, bridge foundations, power plants, and similar projects. Since the annual awards were first given in 1941, recipients have included former President Herbert Hoover, Robert Moses, Admiral Ben Moreell, Peter Kiewit, Harvey Slocum, Louis Perini, and General Raymond A. Wheeler.

William Denny

Mr. Denny, the member recipient, is a native of Sedalia, Missouri. Since 1953 he has been executive vice president in charge of the Construction Department of Merritt-Chapman & Scott Corporation. He joined M-C&S in 1927 after nine years of construction experience in the Midwest, starting as an 18-year-old fireman on a steam rig and working his way up to operating engineer and foreman. Current projects under his supervision include Glen Canyon Dam in Arizona, Priest Rapids Dam in Washington State, and the main generating plant of New York's Niagara Power Project, the three largest competitively bid contracts ever awarded a single contractor.

George M. Drake

Mr. Drake, who received the nonmember award, is a native of Madelia, Minnesota, and is president and general manager of Johnson, Drake & Piper, Inc. He makes his headquarters in Minneapolis. The company, which he helped form in 1914, maintains an international staff of some 300 administrators, supervisors, and engineers, and, at peak operations, has employed as many as 40,000 workers. While still in his teens, George Drake worked as a teamster freighting dynamite and commissary supplies across the Dakota Badlands during the construction of the Milwaukee Road main line. The JDP Company is building a giant installation in Labrador for the Air Force, and in Vietnam and Central America it is constructing highways, buildings, bridge foundations, and dams. One of its recent big undertakings was acting as joint-venture sponsor for construction of 41 miles of the West Delaware Tunnel for the water supply of New York City.

Underground Mining For Cement Rock

Drilling and blasting practices at the Missouri Portland Cement Company are as modern as the new plant

FARRELL CASTELLANI*

EARLY settlers in the Kansas City, Missouri, area, at the confluence of the Kansas and Missouri Rivers, observed the strategic location and beauty of the surrounding countryside from the high bluffs. Little did they realize that some day these bluffs would be the site of a vast underground mining operation for the production of portland cement. This area, historically significant as the start of the Oregon and Sante Fe Trails, is now the site of Missouri Portland Cement Company's newly built cement plant.

The Missouri Portland Cement Company's Kansas City plant was opened at this location in 1906 as the Kansas City Portland Cement Company. Two years later, in 1908, the company was sold to the Union Sand and Material Company and after some years of operation the name was changed to Missouri Portland Cement Company. Originally, the operations at this site started with the material

*Hercules Powder Company
Joplin, Missouri

THE NEW PLANT: Designed to serve the needs of a growing population and an expanding economy, the new plant of the Missouri Portland Cement Company contains every facility for the production of high-quality cement.

being taken from an open-pit quarry but, for more efficient production, a change was made in 1910 to underground mining. Rock loading in those days was done by hand and the quarry cars were hauled by mules, a rather primitive procedure when compared with the modern equipment in today's operation at Missouri Portland.

The new plant is designed to supply the needs of a growing population, an expanding economy, and an increased road-construction program taking place in the heart of America. Completed after five years of building and at a cost of several million dollars, the present plant is a completely new and modern two-kiln operation. An interesting facet of the building of the new plant was that no production was lost during the construction period, as construction went on while the old plant was being dismantled.

The best grades of portland cement require iron, alumina, and silica, in addition to pure limestone. These elements are found in argillaceous materials such as clay or shale. The formation mined at the Missouri Portland Cement Company property is unique in that the vein of material, approximately 36 ft. in thickness, can be blended into a chemically correct and balanced material for making cement.

The Mine

The mine entrance, which overlooks the Missouri River, and the mine floor are approximately 70 ft. above the normal river stage. The material mined is 36 ft. thick. The top 10 ft. of this formation consists of the bottom of the Winterset formation; the middle section is a shale and peanut rock known locally as Galesburg shale; and the bottom formation consists of Bethany Falls limestone. When the shale formation thins out to the point where additional shale is needed, the floor, consisting of Ladore shale, is taken up in the mining operation. It is not often necessary to resort to this, and Ladore shale accounts for only a very small part of the mine's production.

Production of stone for cement making at Missouri Portland is interesting in that three basic methods of underground mining are used in the drilling and blasting phases of the operation.

Drilling and Blasting

The stone production is accomplished by drilling and shooting a so-called hammer cut, vertical drilling, and the use of the modified V cut for driving haulageways.

The hammer cut is used in the mining of the top 18 ft. which consists of approximately 10 ft. of Winterset formation, 4 ft. of Galesburg shale and peanut rock, and 4 ft. of Bethany Falls limestone. The vertical drilling method is used to remove the bottom 18 ft.

As shown in Figure I, the shale section is shot out, the bottom lifted, and the top dropped. The Galesburg shale

LOWER LEDGE: The lower ledge consists of 18 ft. of Bethany Falls limestone 40 ft. wide. Holes are drilled vertically in rows 5 ft. apart, and are loaded with Gelamite 2, 1½ by 24 in., and detonated by short-period delay electric blasting caps.

bottom parting affords a good slip plane, and the shale is broken up very satisfactorily. The subsequent lifting of the bottom and dropping of the top also result in good fragmentation.

The mined dimensions of a hammer-cut round consist of rooms 40 ft. wide and 18 ft. high. A drill round comprises 34 holes, with all holes drilled 10 ft. deep. As most of the horizontal and angle holes are wet-drilled to cut down dust, Gelamite® 2 and 3, 1¼ by 8 in., is used, with the Gelamite 3 being loaded in the shale holes. Short-period delay electric blasting caps, delays 1 to 9, are used and the 34-hole round is fired with a standard-type blasting machine. The shooting is to a natural roof parting in the Winterset formation, which leaves a smooth, hard, and safe roof. The yield is 1 cu. yd. of material per lb. of dynamite. The hammer-cut round now used in the upper ledge replaced a method that had formerly been used in which a V cut was drilled to take out the shale section, the bottom was lifted, and the top dropped. The V cut required more drilling time and dynamite. The results obtained by the hammer cut are as good as, or better than, the previous method and at a considerable saving.

The drilling of the ledge is done with a Joy TM 350 equipped with tandem drills; for mobility the unit is mounted on a Hough Payloader. Conceived by "Pat" Eagan, a Hercules Powder Company technical representative, this machine was designed to drill the upper ledge. This single unit is used to drill all the rock required from the upper ledge and is ideally suited to drill the hammer-cut pattern efficiently. As the floor in this cut is not always smooth, the drilling machine is balanced with hydraulic jacks before any drilling is started. Gardner-Denver 1¼-in. round steel and 1⅝-in. detachable bits are used. The loading equipment consists of a Marion 372 electric shovel with a 2-cu. yd. dipper. A Michigan 175A loader with a 2¼-cu. yd. bucket is also used. All material is loaded into Euclid 80 F D 15-ton units and hauled to a 42 by 48-in. Traylor primary jaw crusher.

The second mining operation involves removal of the lower 18 ft. of Bethany Falls limestone. This operation is started after the top 18 ft. has been blasted and mucked. Holes are drilled vertically in rows 5 ft. apart, just as is done in an open quarry. Rooms are 40 ft. wide and 18 ft. deep. A drill round consists of staggered holes with six holes in the front row, seven in the second, six in the third, and seven in the fourth row. With this drill pattern there are holes at the rib of each row. Gelamite 2, 1⅛ by 24 in., is loaded in all holes and detonated with electric delay caps, with each row being delayed. The round is drilled with a Joy TM 400 B drill mounted on a Ford tractor. Drill steel is 1¼ in. hex. carburized in 10-ft. and 18-ft. sections; carbide insert bits are used.

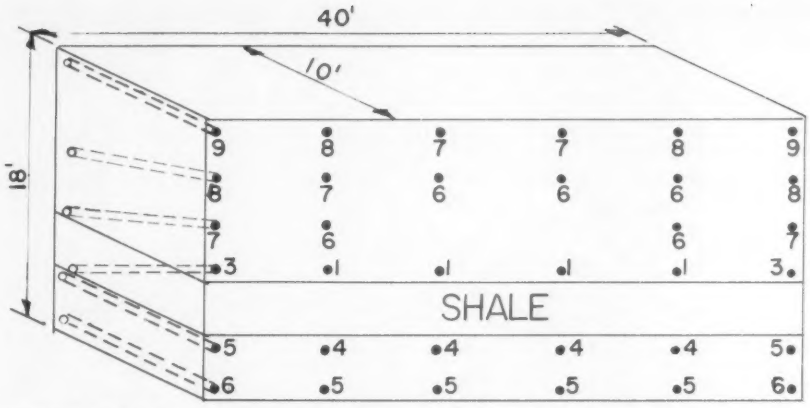


FIGURE 1: The hammer cut is used in mining the top 18 ft. of the face. Holes are drilled to a depth of 10 ft., loaded with Gelamite 2 and 3, and are detonated by using short-period delay electric blasting caps, delays 1 to 9.

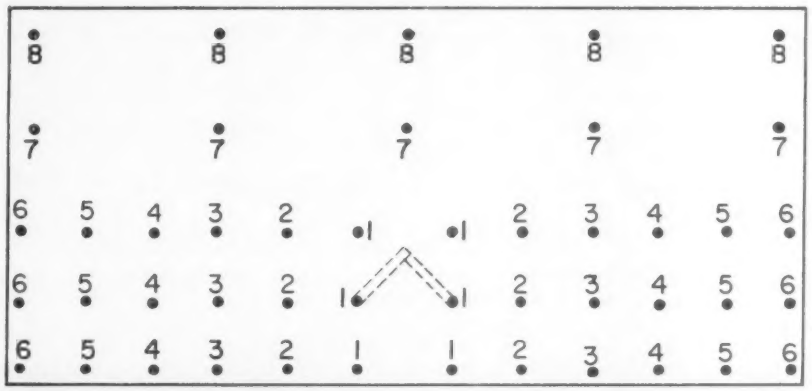


FIGURE 2: A modified V-cut drilling pattern is used in the haulageways. The six V-cut holes, detonated by No. 1 short-period delay caps, are 8 ft. deep, while the remaining holes are full depth and detonated by periods 2 to 8.

The third system of drilling and blasting is employed in the driving of haulageways. This consists of taking 14 ft. up from the floor of the Bethany Falls limestone, and a modified V-cut drilling pattern is employed, as shown in Figure 2. A drill round consisting of 46 holes, a baby V cut drilled 8 ft. deep using short-period electric caps—period 1, followed by numbers 2, 3, 4, 5, and 6—drilled to full depth of the face, completes the V shot. This is followed by dropping the roof, using numbers 7 and 8 short-period delays. Rooms are driven 30 ft. wide and 10 ft. deep. All holes are loaded with Gelamite 3, 1¼ by 8 in. Approximately 225 lb. of dynamite are used to recover 155 cu. yd. of material in a round. Development-work drilling is done with a Markroy electrically powered wet drill with a Joy 350 hammer.

Rock Removal

After blasting, the broken stone from the upper ledge is removed to the main haulageway floor by using ramps designed for that purpose.

ROCK REMOVAL: Just below the Bethany Falls limestone there is a layer of hard shale that makes a smooth haulageway for the trucks that remove the blasted rock.

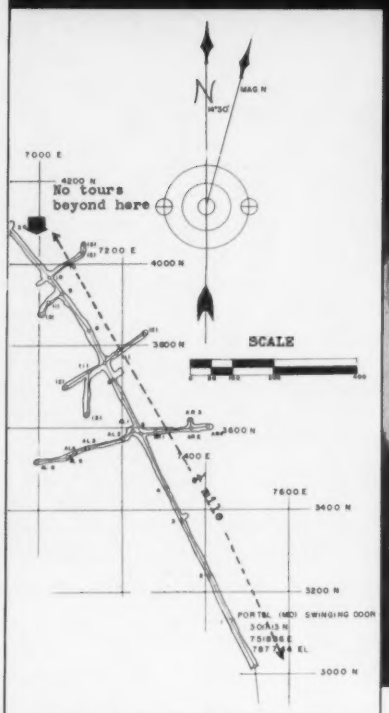
Just below the Bethany limestone there is a layer of hard shale that makes an excellent floor for the haulageways. These haulageways are easy to keep neat and clean and afford smooth transportation.

The material blasted is loaded with a Northwest 80D electric shovel with an enlarged bucket of 3-cu. yd. capacity. A Michigan 175A loader assists when needed. Two stationary compressors—Joy 13½-8-7 class WN 112—furnish air power. Each has a capacity of 700 cu. ft.

Safety comes first at Missouri Portland and all precautions are taken to see that loose and hanging rock in the mining operation is removed by men who do nothing but scale rock from the ribs of rooms.

Underground mining at this operation is geared to the two kilns so that two shifts are used when both kilns are running, and only one shift is employed when one kiln is in operation. Rock requirements for the two-kiln operation are 3,500 tons per day, figured on seven-day operation of kilns.

MINE ENTRY: That safety comes first at Missouri Portland Cement Company's operations is proved by the large red cross and the admonition "Safety First" prominently lettered on the mine entry.



Part of the workings of the experimental mine used by the school.

BLASTING TECHNIQUE: Students utilize the latest in modern equipment in drilling a round for blasting in a raise.

Experimental Mine Used For Instruction in Explosives

Practical experience in drilling and blasting procedures provided for Colorado School of Mines students

ROBERT DYMENT*

COLORADO's history is bright with mineral wealth and tales of prospectors who climbed and clawed their way among the rocky crags and valleys to find the elusive mineral riches or spend themselves in a lifetime of failure. Today, in Colorado, great mines are producing, utilizing the finest mining methods known. Their output has made "Colorado" another name for "mineral" among mining engineers the world over.

Except for the foresight of the Colorado School of Mines, the Edgar Mine at Idaho Springs might be a ghost mine, stripped of a half million dollars in ore. But as a training laboratory for future engineers, the Edgar Mine is still a producer, still contributing wealth, not in ore, but in rich and valuable experience for the men being trained there to exploit the mineral deposits of the world.

The Edgar Mine has been leased for 99 years by the Colorado School of Mines for undergraduate work in mining which cannot be taught in the classrooms. Work carried on there includes mine surveying, mineral land surveying, stoping, drifting, blasting, and the general mechanical engineer-

*220 Central Avenue
Dunkirk, New York

ing of mines. Another important purpose of the mine is to provide a place for mine research and experiments, covering all types of mining studies for further development and increased efficiency.

Mine Is Leased

Dr. James Underhill, who came to the school in 1919, is primarily responsible for the acquisition of the Edgar Mine. At that time, mine surveying was being conducted at the Stanley Mine at Idaho Springs. Its shutdown precipitated the need for another property, and the Edgar was ideal for all intended purposes. The Colorado State Legislature appropriated $20,000 for buildings and the repair of workings, and a long-term lease was obtained from the North American Mining Company of Denver. All of the upper workings were leased by the Colorado School of Mines, and provision also was made for the lower portions of the mine and of the Big Five tunnel that extends under and beyond the mine for a distance of 8,000 ft. Development by the North American Mining Company below the Big Five tunnel went on during the 1930's.

Mine surveying was conducted there exclusively by the school from 1921 to 1932. In 1927, the Edgar shaft was cleaned down to the surface. The year 1935 saw the advent of actual mining operations by the school when the first compressor was purchased. That year was a banner year, as it initiated an expansion of the facilities available. Over the past 32 years the Colorado School of Mines has expended an estimated $100,000 on labor, supplies, and equipment.

The school's experimental mine has been available for industrial research since its opening. Gardner-Denver, which cooperated in the installation of the first compressor, has been using the mine continuously since 1935 for its drill testing.

Three Claims Purchased

Land at the base of the hill road leading to the mine was acquired in 1921, when it was purchased as lots within the city limits of Idaho Springs. In 1949, under the administration of President Ben Parker, the school purchased three claims from the North American Mining Company. These three—the Goodyear, the Sunnyside, and the Newton—were obtained for the sum of $5,000; the present machine shop, change house, and portal are on this land.

The Colorado School of Mines follows manufacturers' recommended procedures for use of explosives and training of students in explosives safety. Both experimental and regular drilling patterns are used.

The vein-type material in the experimental mine contains gold, silver, lead, copper, and zinc. The wallrock is granite. Blasting is performed on both crosscuts and veins.

Drills used are Gardner-Denver,

MACHINERY: A jumbo carriage is one of the mining machines that students study during engineering practice underground.

Cleveland, Joy, and Ingersoll-Rand. The types of drills are drifter, jack-leg, stoper, and jackhammer. Jumbo carriages also are used. Drill steel varies in size from ⅞ to 1¼ in., including 1 and 1⅛-in. sizes. Detachable bits of tungsten carbide, Cleveland throw-away bits, and standard jack bits also are used. Sectional drill steel in lengths of 2, 4, 6 ft., and 8 ft. 4 in. is used for long holes.

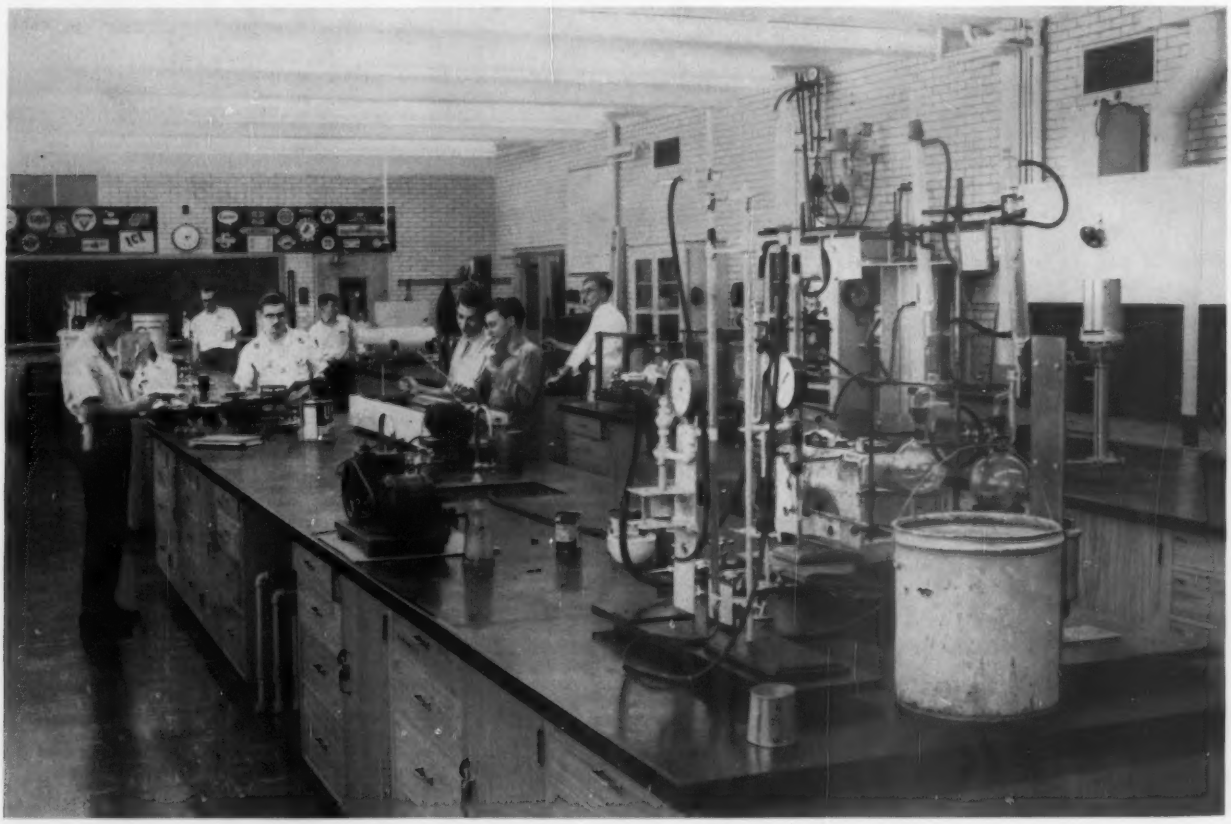
There are two air compressors used in the experimental mine. Both are Gardner-Denvers, one 600 c.f.m. and the other 900 c.f.m.

Diameter, depth, and spacings of drill holes vary in some cases, but, predominantly, are 1½-in. holes, 6 to 8 ft. in depth, with spacing of approximately 18 in.

Hercules dynamites as well as other explosives are used. Common size is 1⅛ by 8 in. in 45% strength. Ordinarily, 3 lb. of powder is used per yard of material in the solid. Stemming or tamping is not used except in experimental rounds, predominantly in advanced graduate courses.

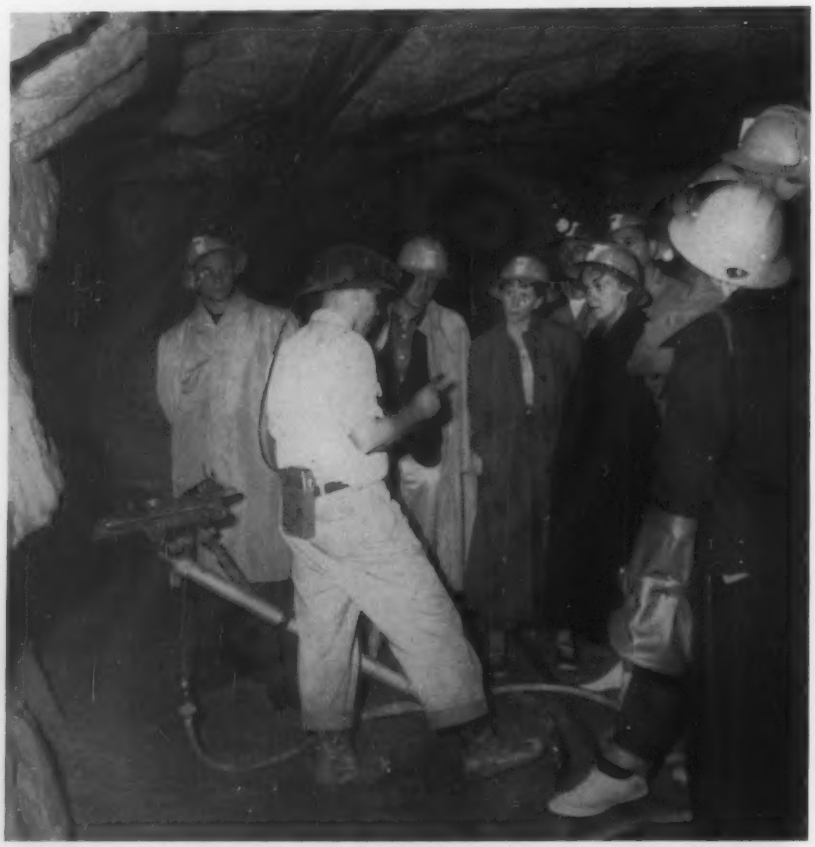
SURVEYING: One of the vital portions of the mining engineering courses taught at the Colorado School of Mines is underground mine surveying in the Edgar Mine.

Detonators utilized here are Hercules, in addition to others, both short-period delay and regular delay types. The detonators are hooked electrically in series or in series-parallel. They are fired with the existing 220-volt power supply. Primary blasts have proved very successful in the experimental



PETROLEUM: A typical summer-session scene in the well-equipped laboratory.

CORES: As part of the mining course, students examine a rock sample taken from a core drill. Currently, there are 153 undergraduate and 15 graduate students enrolled in the course.



TOURISTS: Summer visitors may tour the Edgar Mine, guided by mining engineering students. During the summer of 1959, nearly 11,000 tourists visited the experimental mine.

mine and secondary blasting is not used.

Blasted material is loaded with mucking machines, either Gardner-Denver or Eimco makes. The material is transported in 37-cu. ft. Granby side-dump cars, pulled by a 5-ton Plymouth diesel locomotive. The blasted material is not processed, but disposed of on nearby muck piles.

The school teaches the use of explosives, drilling, and safety practices in the proper classrooms—before the students enter the mine.

A Required Course

Every student enrolled in mining engineering (there are now 153 undergraduate students and 15 graduate students) is required to take the mining engineering laboratory course. This course teaches the fundamental operations of underground mining, including drilling, blasting, mechanical loading, haulage, and support practices as applied to drifting, raising, and winzing. Managerial aspects and the integration of unit operations also are studied. The course is taught on 15 Saturdays and holidays during one semester, eight hours a day. For this amount of work, the student receives two semester hours of academic credit.

The classes average 35 men each semester, and either a mining instructor or a trained shift boss supervises each group of six students. Maynard Ayler, instructor in mining engineering, is in charge of the mine.

The experimental mine also is used for other purposes. Gardner-Denver and other mining machinery manufacturers use the mine to experiment with new machinery developments. The Colorado School of Mines Research Foundation uses the experimental mine as a laboratory for mining engineering research projects. During the summer months a certain portion of the mine is opened to tourists. During the summer of 1959, nearly 11,000 tourists made guided tours of the mine. These free tours are guided by several mining students who staff the mine during the summer months.

Thus, the Colorado School of Mines and its experimental mine are playing an important part in supplying trained engineers and executives for the mining industry.

NEWS NOTES

PORTABLE COMPRESSOR BULLETIN

All-weather operation and other exclusive features of six models of rotary portable air compressors ranging from 85- to 900-c.f.m., are described in the new Gardner-Denver Company bulletin, "Rotary Portable Compressors."

The eight-page pamphlet (RC-1) gives specifications for the small 85-c.f.m. air-oil-cooled Model RP85, as well as the five larger water-oil-cooled compressors, and pictures typical heavy-duty applications.

The engineering principles responsible for all-weather operation and the elimination of "dry starts" during cold weather are fully described and illustrated.

Copies of the bulletin can be obtained by writing to Gardner-Denver Company, Quincy, Illinois.

SAFETY FILMS

The National Safety Council has announced release of a series of four training films entitled "Communication for Safety."

They are described as a fresh, realistic solution to the ever-present problem of communication. The films use everyday supervisor-worker situations, plus an effective combination of live-action photography and clever animation to achieve maximum believability.

Available either individually or in series of four, the films come in two sizes – 16-mm. sound motion picture, and 35-mm. sound slide film.

Further information on "Communication for Safety" may be obtained from the National Safety Council, 425 North Michigan Avenue, Chicago 11, Illinois.

NEW JOY AIR HOIST

A new air-powered hoist by Joy Manufacturing Company offers a choice of several throttle and brake systems that make it adaptable for use in such divergent areas as mine shafts for hoisting men and materials, car spotting at industrial plants and mines, submarine drill barges as anchor or spud hoist, barge spotting at docks, decoking tank service. The hoist has a lifting capacity ranging from 27,000 lb. at 37 f.p.m. to 3,700 lb. at 220 f.p.m.

For portability, the entire assembly is mounted on a skid-type base. According to Joy, this one-piece welded steel base keeps all parts in permanent alignment. All controls for the new JCP-120 hoist are mounted on the hoist in the standard model but can be removed and operated from a remote position. The JCP-120 hoist can also be equipped with electric motor drive of 10 to 25 hp. or air-cooled gasoline or diesel engine drive.

For more details, write to Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pennsylvania.

NEW STEEL SHEET PILING CATALOG

A new 24-page catalog on steel sheet piling is available from L. B. Foster Company. It discusses advantages of renting sheet piling, illustrates typical applications, and details standard, rolled, and fabricated sections. The catalog also illustrates typical pile arrangements for rectangular and circular cofferdams, and lists nominal lengths of straight walls and dimensions of pile cells. Special sections describe lightweight sheet piling, H-bearing pile, Foster rail pile, pipe pile, and accessories.

Catalog 400 points out that renting sheet piling eliminates the need for substantial investments in inventory stocks and tie-up of capital. To obtain a copy of Catalog 400, please write to L. B. Foster Company, P. O. Box 1647, Pittsburgh 30, Pennsylvania.

DISPOSABLE PROTECTIVE SUIT

Safety First Supply Company has introduced a new all-purpose disposable plastic safety suit designed to protect workers in all industrial operations involving exposure to chemicals, water, and excess dust or dirt.

According to the manufacturer, this lightweight plastic suit is resistant to most acids and alkalies and fire as well as being waterproof and unaffected by oil or grease. The light-yellow polyvinyl chloride slip-over jacket and trousers fit comfortably over ordinary work clothing. Elastic tape at neck, wrists, and ankles assures a tight fit for additional protection against dust, sprays, and splashes.

Further information and quantity prices may be obtained by writing Safety First Supply Company, 421 Magee Street, Pittsburgh 19, Pennsylvania.

UTILITY FIELD HOUSES

Two sturdy all-steel utility buildings have been designed by Martin Steel Corporation, Mansfield, Ohio, for building and construction crews' field houses. The manufacturer claims that both prefabricated buildings provide the safest and surest safeguard for tools and equipment, are economical and easy to erect, and make practical worksheds for any job. More important, they can be readily dismantled for moving to another job site.

The 7 by 7 by 7 ft. Martin Stor-House provides a contractor's ideal field house for any construction job. Wide 4-ft. double doors give easy accessibility to tools and supplies stored within.

The Martin "101" Building, so named for its more than one hundred and one uses, is the larger utility building which comes in a variety of sizes. It is very flexible, making it suitable to individual needs, especially on larger construction jobs.

NEW FLASHER SIGNALS

New 5- and 7-in.-diameter flasher warning lights with a 1-in.-wide brilliant circle of light around the rim are being introduced by Pacific Mercury.

A bulletin states that the new lights are available in amber and red, and have been designed to offer greater nighttime visibility and traffic safety. Flash rate of the lights is adjustable to meet specific state highway requirements, and maximum "on" time has been extended 25 to 30% to meet state highway requirements now in effect in Illinois, Michigan, and Nebraska.

The manufacturer states the lights are vaporproof, completely safe for use in the presence of gasoline or explosive vapors. Both models are available with tamperproof switch and PM's exclusive "Solarstat" for automatic turn-on as the sun goes down, turn-off when the sun rises. Thick, shatter-resistant, optical-quality lenses and cast copper-aluminum housing drastically reduce possible collision damage, insure long service life.

For more information, write to Pacific Mercury, 13232 Leadwell, North Hollywood, California.

NEW "SPRAWLER" CRANE

The Model 330 "Sprawler," a new crawler-mounted crane able to lift more than its own weight, has been announced by the Koehring Division of Koehring Company.

The manufacturer states that the Model 330 is designed to combine high lifting capacity with ease of transportation, and is equipped with the same pivoting outriggers used so successfully on Koehring's 545 Sprawler.

With the outriggers set, the 330 Sprawler can lift 60,000 lb. working with a 30-ft. boom at a 12-ft. radius. With the outriggers folded against the crawlers, the new crane will lift and carry 47,980 lb., with a 30-ft. boom at a 10-ft. radius.

Further information is available from Koehring Division, 3026 West Concordia Avenue, Milwaukee 16, Wisconsin.

PAVING BREAKER BULLETIN

A heavyweight paving breaker (Blue Brute WB-82), designed for outstanding performance on the heaviest demolition work, has been introduced by Worthington Corporation. According to the manufacturer, weight, balance, and smoothness favor the operator. The progressive throttle valve simplifies starting moils under adverse conditions, and features such as the bushed front head and throttle valve combined with blue-coated parts assure prolonged efficient operation at minimum maintenance costs.

The WB-82 is available with spike driver (for spikes to 1¾-in. heads) and sheeting driver (for wood sheeting 2 to 3 in. thick) front heads, which are readily interchangeable with the standard paving breaker housing.

For additional facts, see your nearby Worthington distributor or write to Worthington Corporation, Holyoke, Massachusetts.

MULTIPLE-USE FIRST-AID UNITS

The new M-S-A flip-top box for multiple-use first-aid units is described in a bulletin just issued by Mine Safety Appliances Company, Pittsburgh, Pennsylvania.

An illustrated bulletin highlights construction features of the new container, including resistance to tearing after frequent use, sealed-in protection against dust or grime, and improved convenience in extracting items.

M-S-A first-aid items in the new package are listed as ammonia inhalants, iodine brushes, merthiolate swabs, waterproof adhesive bandages, plastic adhesive bandages, 2-in. compress bandages, Foille liquid for burns, in two sizes, and Foille ointment for burns.

The bulletin, No. 0401-8, is available on request from Mine Safety Appliances Company, 201 North Braddock Avenue, Pittsburgh 8, Pennsylvania.

CIRCUIT BREAKER ACCESSORIES BULLETIN

A new 12-page, two-color bulletin describing G-E's complete line of industrial molded case circuit breaker accessories and modifications is now available from the Circuit Protective Devices Department, General Electric Company.

The new publication, GEA-6757, provides all information necessary to select, specify, and order G-E circuit breaker accessories and modifications. All products are fully illustrated and the text is supplemented by outline dimensional drawings.

The new bulletin may be ordered by writing for GEA-6757 to General Electric Company, Distribution Unit, 90 Whiting Street, Plainville, Connecticut.

VIBRATIONS

(Continued from page 19)

connection. Table II lists the velocity of compressional waves and the characteristic impedance for some common rock types.

[2]David E. Fogelson, Wilbur I. Duvall, and Thomas C. Atchison, "Strain Energy in Explosion-Generated Strain Pulses," *U. S. Bureau of Mines Report of Investigations 5514* (1959).

In the blasting of rock, breakage and the resultant by-product vibrations are directly related to the amount of energy transferred from the explosive to the rock, and the efficiency with which this energy is transmitted through the rock.

U. S. Bureau of Mines investigators[3] found that of the total energy computed for several test explosives, from 10 to 20% was transferred to a granite in which they were detonated. They pointed out, moreover, that within the range of their experiments the amount of energy transferred to a given rock was a linear function of the characteristic impedance of the explosive (see Table I). They concluded that "*explosives that had the larger characteristic impedance, or impedances more nearly matching the characteristic impedance of the rock, transferred more energy to the rock.*"

In this connection, the method of packing explosives into boreholes becomes a factor, since the impedance of both rock and explosives is of the order of 10,000 times that of air. This very large contrast in impedances causes serious energy losses in transferring from explosive to air and from air to rock.

EDITOR'S NOTE: *The second, and final, installment of Dr. Leet's article will be presented in the March-April, 1960, issue of* THE EXPLOSIVES ENGINEER.

Table II
COMPRESSIONAL WAVE SPEEDS AND CHARACTERISTIC IMPEDANCE FOR CERTAIN ROCKS

Rock	Velocity of Compressional Waves ft./sec.	Characteristic Impedance lb.-sec./in.[3]
Granite	18,200	54
Marlstone*	11,500	27
Sandstone	10,600	26
Chalk†	9,100	22
Shale	6,400	15

*A hardened mixture of clay materials and calcium carbonate, normally containing 25 to 75% clay. A type of limestone.

†A very soft limestone.

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Over 15 ft. per hr. through solid granite

with Stardrill-Keystone KF-50 rotary gun drill

This production — reported by B&R Diamond Drilling Co., of El Cajon, California — shows again why more Stardrill-Keystone rotary drills are sold for the tough jobs. On the KF-50 application pictured, operator used tricone rotary rock bit to drill down to solid rock, then switched to down-the-hole air hammer to sink 15 ft. per min. through solid blue granite. Water-cooled piston compressor lifted cuttings thru water from 300 ft.

Handles scattered mine, quarry work

Heavy duty in every respect, the KF-50 mounts a Cummins diesel engine, a 500 CFM two-stage compressor, a 158 gpm duplex piston mud pump, and has retractable rotary table. Variable-speed pull down, with infinite feed adjustment from 0 to 20 ft. per min., insures maximum permissible hole production in any type formation. Bit pressures to 30,000 lbs. are obtainable. Depending on your needs, mud pump can be omitted, with larger-capacity compressor available.

Get the complete story on the truck-mounted KF-50. You'll find it "has what it takes" to cut your costs on blast hole drilling, sampling, and exploratory work. Get in touch with your Stardrill-Keystone distributor, or write for complete specs.

Stardrill-Keystone offers a wide range of rotary, down-the-hole, and combination drills, tools and attachments for mining and quarry applications. Your Stardrill-Keystone representative is available to make specific recommendations for your particular problem without obligation.

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at Rocky Reach Dam

This concentrated battery of fast-acting, mobile drilling power is sinking 25 to 30 foot holes for the main power house excavation at Rocky Reach Dam on the Columbia River, north of Wenatchee, Washington. Under construction by the Rocky Reach Contractors, this major project is a joint venture sponsored by the L. E. Dixon Company of San Gabriel, Cal. For high sustained drilling speeds, these six Ingersoll-Rand Crawl-IR drills are using 2¾" Carset bits and I-R Carburized Drill Steels.

The Crawl-IR units are also used to drill 90 foot grout holes around the circumference of the coffer dam.

Ingersoll-Rand Crawl-IR drills are completely mechanized, heavy-duty units that convert setup time into *drilling time*. All motions—raise, lower, horizontal swing, extend, retract, and tower dump and swing—are powered by large, double-acting hydraulic cylinders, throttle controlled from a central operating station on each drill. Rugged I-R air traction motors, independently controlled, move the drill from place to place—permit fast, accurate hole spotting.

Ask your Ingersoll-Rand rock drill engineer for the inside story on why Crawl-IR is the strongest, most rugged crawler drill ever developed. Or send for new Bulletin No. 4208.

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When the compressor stops operating, the receiver blows down automatically. This eliminates the possibility that the operator will forget and try to start the machine under load.

All portables have a safety circuit, but on most of them a broken wire will make the circuit inoperative. On Joy rotaries, the compressor cannot be operated unless the safety circuit is complete and working perfectly—eliminating a possible source of major compressor damage.

Every Joy rotary has an automatic drain system designed to prevent hydraulic lock. Standard equipment also includes a thermal bypass valve which prevents dry starts and eliminates moisture condensation.

Even common items like the oil filter have been given special attention. Instead of a filter that requires cleaning periodically, Joy rotaries have replaceable element filters—just put in a new element whenever you change oil.

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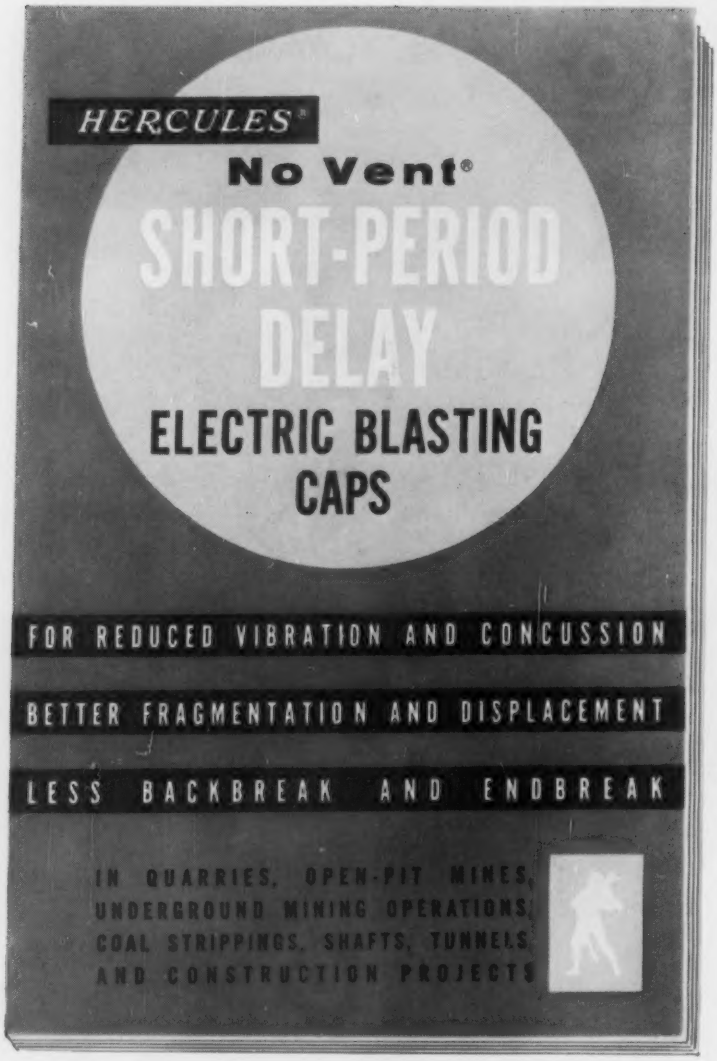
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